A FIVE-YEAR STUDY OF A HIBERNATING COLONY OF *MYOTIS LUCIFUGUS*[1]

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ABSTRACT

A hibernating colony of *Myotis lucifugus* was studied for a five-year period. The members of the colony exhibited movement within the cave system during the winter months. The expectancy of finding a bat present in the cave was approximately two- and-a-half years after banding. The average distance of bats recaptured was 25±5 miles from the banding site.

The availability of banding records has enabled investigators to study the behavior and structure of hibernating bat colonies. In spite of the large number of bats banded annually, numerous questions remain unanswered regarding the behavior, ecology, and structure of these colonies. The problem of insufficient band returns, in addition to the problem of individual bats changing their hibernating site from year to year, continually plagues investigators. Furthermore, the annual variability within a colony may be too great to justify the time and expense in the exact precision estimate in prediction of population numbers. Davis (1960) indicated that life expectancy can be calculated from the probability of survival as long as the age or the date of breeding is clearly defined and the population size at each interval is known. Since the determination of the exact age of an individual at banding may be exceedingly difficult, the life expectancy may be more clearly defined as the length of time that a segment of the population is present in a colony in subsequent years following banding.

Another problem that confronts investigators involves the local movements of individuals within the cave system or the existence of movement between colonies as suggested by Hall (1962) and Daan and Wichers (1968). Moreover, the analysis of banding records and populations suggests that this may be a common phenomena among bat populations. This study involves the analysis of five years of banding records as prediction of behavior and structure of a bat population.

METHODS

The study was initiated in 1965 with the colony being visited once or twice a year for five years. Laurel Caverns is a commercial cave located seven-and-one-half miles southeast of Uniontown, Fayette County, Pennsylvania. Commercialization of the cave began in 1963 and the caverns were opened to the public in the summer of 1964. The section of the cave inhabited by bats remained in a natural state, consisting of three large rooms connected by narrow passages. All the bats observed in rooms one and three could be collected without difficulty, but the high ceilings in room two prevented the collection of between 50 and 75 bats that inhabited the inaccessible portions of the room (fig. 1). Bats were collected in each room, banded and released. The cave was visited during November and February in 1966, 1967, 1968 and 1969 to determine the movement of bats within the cave as well to obtain a population estimate. The relative humidity and ambient and substrate temperatures were determined at the end of the commercial area and in the areas inhabited by the bats.

The length of time that members of a population would be expected to remain in a colony was calculated from the population of banded individuals present in the population in years subsequent to banding referred to as the probability of survival by Davis (1960). The starting date of an age class was November and the life

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expectancy was calculated by a method described by Davis (1960): where 1_c = the time interval in years; 1_x = the number alive at each time interval; L_x = an approximation to the average alive during the time interval and is strictly the average of initial and final population or $\frac{(1_x+L_x+1)}{2}$. T_x is the cummulated total of live individuals from the end of the column L_x, which is the total number of years that a bat may be expected to be present in the colony by L_x individuals.

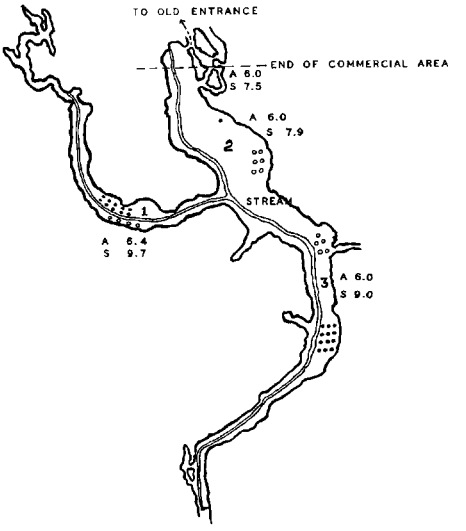

FIGURE 1. The hibernation of *Myotis lucifugus* in Laurel Caverns during November and February. Each circle represents ten individuals and the clear and solid circles represent November and February, respectively. (A = air temperature; S = substrate temperature).

From this: E_x is $T_x/1_x$ where E_x is the life expectancy or length of time that the members of each age class can be expected to be present in the population. Only age group four and five were combined because of the low number of returns present in the fourth and fifth years following banding. These values may not be an exact life expectancy but an indication of the length of time that an individual would be present in a colony. The movement of bats from the hibernating colony was determined by bands returned to the U.S. Fish and Wildlife Service Bat Banding Office.

RESULTS AND DISCUSSION

A total of 2,914 bats were banded during the five years of study. The population was estimated by the mark and recapture method in the winters of 1966 through 1969. In this three-year period, the number of bats visiting the cave was estimated to vary between 3,000 and 6,000 individuals. However, in these same three years between 788 and 892 individuals were captured (table 1) and all but 50 to 100 of the bats observed in the cave accounted for 11 to 14 percent of the estimated population visiting the cave during the winter (table 1). The proportion of males in the population varied between 62 and 83 percent and did not appear to change seasonally except with the possibility of February 1969 (table 2).

Numerous other investigators have reported disproportionate sex ratios among hibernating bat colonies in the eastern United States (Griffin, 1940; Mohr, 1945;

TABLE 1
Estimated population size of Myotis lucifugus *in Laurel Caverns, Pennsylvania from 1966 through 1969.*

Year	Population estimate		% of estimated population observed in colony
	Male	Female	
1966–67	3100±230	2500±360	14.1
1067–68	2400±710	800±230	28.0
1968–69	3900±1000	2300±500	11.3

Hitchcock, 1949; Hitchcock and Davis, 1964; and Davis, 1959). These studies indicated that males comprise between 60 and 80 percent of hibernating colonies of *Myotis* sp. *Eptesicus fuscus* and *Pipistrellus subflavus*. However, considerable variations have been shown to exist in the sex ratios from one cave to another, as well as in different geographical areas.

TABLE 2
The number of Myotis lucifugus *banded and the proportion of males present in Laurel Caverns during a five-year period.*

	N	1965 ♂	N	1966–67 ♂	N	1967–68 ♂	N	1968–69 ♂	N	1970 ♂
November	127	61.5	215	67.5	394	72.0	208	76.9	515	72.5
February	—	——	573	68.6	498	72.0	384	82.5	—	——

Bats were observed in greater numbers during November in Room One and apparently aggregated in Room Three in February (fig. 1). This apparent movement was supported by the observation that bats banded in room one during November were recovered in room two and three in February, while bats tagged in room two and three during November were recaptured in these rooms in February (table 3). These movements might have been due in part to the disturbances

TABLE 3
The movement of Myotis lucifugus *banded in November and recaptured during February in Laurel Caverns.*

Room	Total banded in November	Percent recaptured in February		
		Room 1	Room 2	Room 3
1	414	0.9	2.0	2.7
2	23	0.0	4.8	0.0
3	233	0.0	2.9	5.8

resulting from banding, but since all bats were released at a central locations and approximately the same amount of time was spent in each room, these activities were probably not a major contributing factor to the relocation of bats. Bats were apparently present in slightly larger numbers in February than in November (table 2). This aggregation of bats did not appear to be in response to temperature since the air and substrate temperatures were approximately the same in both

rooms one and three. However, the lack of a large number of bats in room two may be related to the cooler substrate temperatures. The relative humidity was approximately 68% in all three rooms. Therefore, the distribution of bats was probably related, at least in part, to temperature but not to relative humidity.

The probability of finding a bat in a cave following banding was greater for males than for females. However, the length of time that an individual bat could be expected to be present in the population (table 4) was similar for both sexes.

TABLE 4

Life expectancy and survival rates of bats in Laurel Caverns based on band recoveries.

Age group		Male		
x	l_x*	L_x*	T_x*	E_x*
0	1000	537	719	0.72
1	74	68	182	2.46
2	62	58	114	1.84
3	53	41	56	1.06
4	29	15	15	0.52
		Female		
0	1000	513	574	0.57
1	26	24	61	2.54
2	22	18	37	1.18
3	14	13	19	1.35
4	11	6	6	0.55

*l_x=number alive at each time interval.
L_x=average of initial and final population.
T_x=cumulated total of live individuals.
E_x=life expectancy of members of each age class.

For example, if a bat survives the first year after banding, these individuals may be expected to be present in the population for approximately two-and-a-half years. Humphrey (1971) stated that the highest minimum survival, calculated from 71,706 banded *M. lucifugus* were relatively low in the first year after banding but were relatively constant in subsequent years. Therefore, this expectancy estimate may be a useful figure in determining the length of time that a particular segment of a population would remain in the hibernacula following banding. Furthermore, since it is possible to obtain this estimate from relatively few returns, this could eliminate unnecessary time and expense in banding large numbers of bats. The proportion of banded bats present in the population from previous years was 17.6 percent in November and 14.6 percent in February for males, while for females it was 9.0 percent and 9.4 percent for November and February, respectively. Hence, the number of unbanded individuals accounted for approximately 84 percent of the male members and 91 percent of the female members of the population. A recruitment of this magnitude could not be accounted for by reproduction; hence, some immigration must occur from other populations.

Bats were recaptured at distances varying from approximately 9 to 90 miles away from the hibernating colony. The average distance for the 21 bats recaptured was 25±5 miles from the banding site (fig. 2). The sexes of the bats recaptured consisted of 17 males and 2 females. The largest number of returns

was during the month of July with eight, and four returns each month were obtained during September and November, respectively. One returned during May and two in June. The majority of the returns were from locations northwest of the hibernating site in close proximity to the course of the Monongahela River and occurred during the late summer and early fall, indicating that they were probably returning to the hibernating colony. This migratory movement was not due to the break-up of maternity colonies, since the majority of the returns were males and these results are consistent with those of Hall and Brenner (1968).

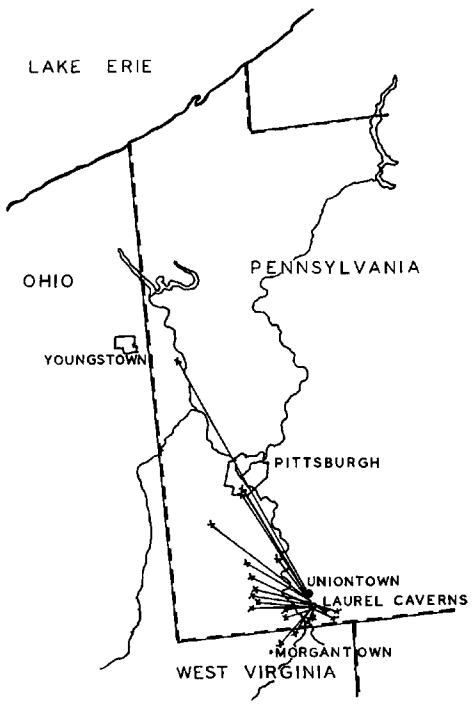

FIGURE 2. The dispersal of bats from Laurel Caverns as calculated from bands returned to the U.S. Fish and Wildlife Service.

By capturing bats with mist nets at the entrance of Aiken Cave in Pennsylvania, it was found that *Myotis lucifugus* began to visit caves beginning in early July and continued throughout the remaining summer and early fall. In Hall and Brenner's (1968) study, 571 and 485 bats were captured and banded during the summers of 1964 and 1965, respectively. However, the following winters, 14.3 percent and 11.1 percent, respectively, of the summer visitors were members of the hibernating colony. Hall and Brenner (1968) stated that these recoveries indicated that the summer population was approximately 3980 and 4370 in 1964 and 1965, respectively. The winter colony of Aiken Cave consisted of 15 percent of the summer transients. This transient movement of bats indicated that a large number of bats visit a cave system but hibernate elsewhere. Furthermore, Hall (1962) states that females tend to change their cave of hibernation more than males, and Tinkle and Patterson (1965) and Daan and Wichers (1968) indicated that various species of bats tend to change their hibernation site from year to year as well as periodically during the same winter.

This movement of bats between caves and/or within a cave system complicates

the calculation of a precise estimate of bats present in a hibernating colony. The estimated population based on banding returns suggests that many more bats are present in the cave than were observed during any visit. Moreover, the number of banded individuals observed in Laurel Caverns in subsequent years following banding suggests that movement occurs between caves and/or within a cave system. These movements may account in part for the disproportionate sex ratios that have been observed, since females may tend to change their hibernation site more than males.

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Tropical Macrofungi—Some Common Species. *M. H. Zoberi.* Hafner Publishing Company Inc., New York, 1972. xvi+158 p., 46 figs., 4 color pl. $16.95.

This very expensive little book represents a systematic account of 104 species of tropical macrofungi, about half of which are cosmopolitan; several are either rare or infrequently encountered. Contrary to the title, which conveys the impression of a worldwide compilation, emphasis is placed on species collected and described by the author in West Africa. Forty-six of these are figured as line drawings by the author's wife and 16 by full-color photographs on 4 plates.

The book, according to the author, was designed as an aid for identifying some of the attractive macrofungi one might find in the tropics and, at the same time, as a contribution to an area of mycology almost totally barren of such literature. The author is to be complimented on both objectives, although neither is completely achieved in this work. The greatest fault is probably not that of the author, but largely of the publishing company itself. At $16.95 this book is out of reach for most students in tropical countries and to those in other parts of the world as well. One must seriously question, therefore, the value of this contribution if it is generally unavailable to those for which it was specifically intended.

There are a number of misprints throughout the text. The diagnoses are inconsistent with respect to the details included and in some cases include cumbersome and irrelevant details. The compilations are, however, accurate. The line drawings are realistic in form, but lack magnifications, captions, and specific morphological characteristics. The color photographs are of little use in making specific or generic determinations and could have been omitted, thus reducing publishing costs.

Having used this manual in the tropics, I find the lack of keys to species a serious handicap to the user. As a result, one must in many cases plod through many lengthy descriptions before finding the correct species or discovering that it is not even included in the book.

There is a great need for manuals dealing with fleshy fungi of the tropics. The author should be encouraged to continue his endeavors, but with more consideration given to the cost and scope of subsequent publications.

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